Fermilab

TM-774
2251.0

Estimated Event Rates For Beam Dump Experiments

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March 8, 1978

In this report I assume that the proton beam is dumped in an aluminum or copper dump in Enclosure 100. Neutrino and antineutrino fluxes and event rates were calculated for the 15-ft Bubble Chamber located 1000 m from the dump. The incident proton energy is 400 GeV. Absorption lengths for π^+, π^-, K^+, K^-, and K_L^0 were assumed to be 62, 59, 80, 70, and 75 cm, respectively. Only particles produced at the primary proton-nucleus interaction were taken into account, and secondary, tertiary or other processes were neglected.

Computed neutrino and antineutrino fluxes are shown in Figure 1 for an incident proton angle of 0 mrad. Solid curves correspond to fluxes when decay lengths for pions and kaon were assumed to be zero. Dashed curves are fluxes for the aluminum dump. Also shown is the ν_μ flux for the double horn system for comparison. Stefanski-White's parametrization[1] was used for charged pion and kaon production cross sections. The K_L^0 production cross section was assumed to be the average K^+ and K^- cross sections. Figure 2 shows summed fluxes for the four kinds of neutrinos at 0 mrad. Also shown are prompt electron neutrino fluxes from D(1.86) decays. Electron neutrino energy distributions from the D decays and the form of production cross section of

D's were taken from I. Hinchliffe-C. H. L. Smith[2]. We assumed $\sigma \cdot B = 8.8\ \mu b$.

The angular dependence of muon neutrino fluxes for π^+ and K^+ decays and electron neutrino fluxes for D(1.86) and kaon decays are shown in Figures 3 and 4. Angular intervals are 0 to 2, 4 to 6, 8 to 10, and 18 to 20 mrad.

Table I lists calculated numbers of neutrino events for various processes. The total number of incident protons is 10^{18} at 400 GeV. The total cross sections for both electron and muon neutrinos and antineutrinos were assumed to be $0.74\ E_\nu \times 10^{-38}$ and $0.28\ E_{\bar{\nu}} \times 10^{-38}\ cm^2/GeV$, respectively. Event rates for backgrounds are given for copper and aluminum dumps. Event rates for $D \to Ke^+\nu_e$ or $K^*e^+\nu_e$ decay with $\sigma \cdot B = 8.8\ \mu b$ are roughly consistent with the recent CERN BEBC results.[3] From Table I we can conclude the following:

1. Electron neutrino and antineutrino backgrounds are substantially small even for the aluminum dump compared to the event rates observed at CERN. Therefore, the signal to background ratio is reasonably good for the 15-ft Bubble Chamber using the aluminum dump at 0 mrad.
2. The neutrino detectors at Lab C and Lab E cannot identify electron events from muon events. Electron events look exactly like muonless neutral current events. The cleanest signals for those detectors are μ^+ events. Unfortunately, even μ^+ events for the aluminum dump at 0 mrad seem to be marginal. A dump with heavier material such as copper is desirable.

and

3. Neutrino/antineutrino fluxes from the D decay decrease slowly as the incident proton angle increases. On the other hand background fluxes from pion and kaon decays decrease rapidly. In order to determine whether sources of prompt neutrinos and antineutrinos are due to charm production, it is vital to vary the incident angle of the proton beam.
4. Although detailed study of muon and electron neutrino (and antineutrino) events in the 15-ft Bubble Chamber should give a good estimate for background event rates from pion and kaon decays, it is desirable to change the dump density.
5. Since event rates are limited particularly for the Bubble Chamber, 10^{18} protons on the dump at Enclosure 100 for each configuration would be a desirable minimum. Therefore, if the dump is moved to the target tube which can provide flexible dump arrangements, twice as much running time is required for the 15-ft Bubble Chamber and the detectors at Lab C and Lab E, and four times for the detectore at the Muon Lab and the Wonder Building which have relatively small masses. The schematic drawing of the physical layout of the target tube, decay pipe, beam dump, Enclosure 100, and the neutrino detectors is shown in Figure 5.

Figure 6 shows angular distributions of electron neutrino fluxes for $e^{+}\ {}_{e}$ decays of postulated particles with masses of 300, 500, and 1000 MeV. Particle productions were assumed to be similar to positive pions.

In conclusion, it seems to be essential to have a beam dump system in Enclosure 100 and to vary the incident angle of the proton beam and the dump density in order to uncover the mystery of prompt neutrino phenomena.

Valuable discussions with Professor D. Cline, Dr. M. Gilchriese, Dr. D. Theriot and Dr. T. Yamanouchi are greatly acknowledged.

References

1. R. Stefanski and H. White, Jr., FN-292, 1976.
2. I. Hinchliffe and C. H. Llewellyn Smith, Nucl. Phys. B114, 45 (1976).
3. J. Fry, private communication.

θ (mrad)	E_ν (GeV)	$D(1.86)\to K e^+\nu_e / K e^-\bar{\nu}_e$ $\sigma B=8.8\mu b$	$D(1.86)\to K^* e^+\nu_e / K^* e^-\bar{\nu}_e$ B=8.8 b	ν_μ (π^+,K^+) Cu/Al	$\bar{\nu}_\mu$ (π^-,K^-) Cu/Al	ν_e (K^+_{e3},K^0_L) Cu/Al	$\bar{\nu}_e$ (K^-_{e3},K^0_L) Cu/Al
0	0- 50	6.4/2.4	8.1/3.1	34/85	6.3/16	1.3/3.3	.28/.71
	50-100	13 /5.0	12 /4.5	18/44	1.6/4.1	.9/2.3	.13/.32
	100-150	7.3/2.8	3.5/1.3	9/21	.3/ .8	.3/ .7	.04/.10
	150-200	2.1/ .8	.7/ .3	4/10			
	Total	29 /11	24 /9.2	64/161	8.2/21	2.5/6.3	.4 /1.1
5	0- 50	6.3/2.4		14/36		.74/1.9	
	50-100	9.6/3.6		6/15		.19/ .5	
	100-150	3.6/1.3		2/ 5			
	Total	21 /7.3		22/56		.93/2.4	
9	0- 50	5.6/2.1		6.7/17		.38/.96	
	50-100	6.4/2.4		1.6/ 4.1		.04/.10	
	100-150	1.2/ .4		.2/ .4			
	Total	13 /4.9		8.5/21		.42/1.1	
19	0- 50	3.3/1.2		1.9/4.7		.09/.21	
	50-100	.8/ .3		.1/ .2			
	Total	4.1/1.5		2.0/4.9		.09/.21	

Table I. Event rates at the detector of 20 tons located 1000 m from the dump. The total number of protons is 10^{18} at 400 GeV. θ is the incident angle of the proton beam on the dump.

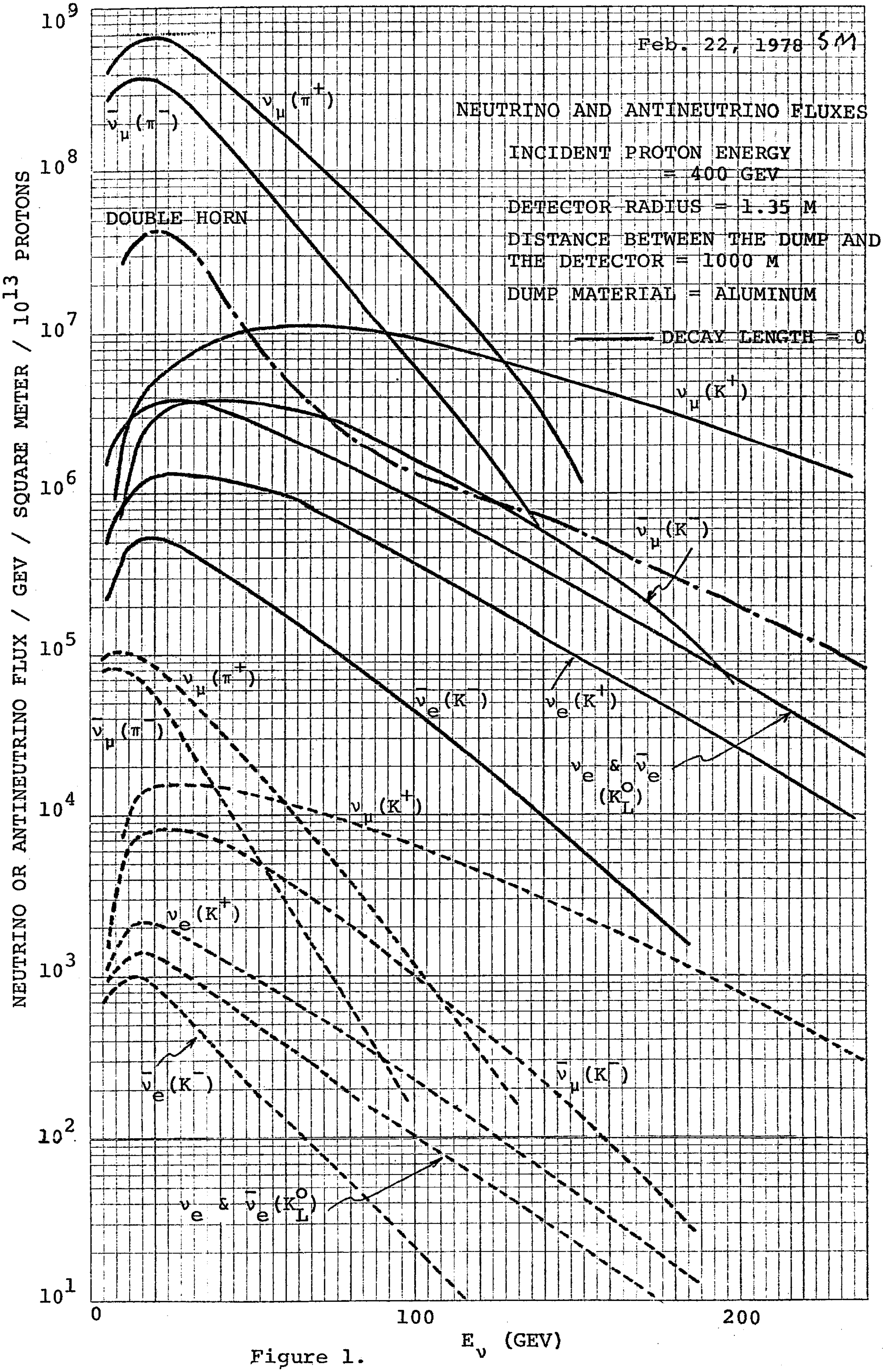
Feb. 22, 1978 SM
NEUTRINO AND ANTINEUTRINO FLUXES
INCIDENT PROTON ENERGY = 400 GEV
DETECTOR RADIUS = 1.35 M
DISTANCE BETWEEN THE DUMP AND THE DETECTOR = 1000 M
DUMP MATERIAL = ALUMINUM
DECAY LENGTH = 0
DOUBLE HORN
$\nu_\mu(\pi^+)$
$\bar{\nu}_\mu(\pi^-)$
$\nu_\mu(K^+)$
$\bar{\nu}_\mu(K^-)$
$\bar{\nu}_e(K^-)$
$\nu_e(K^+)$
ν_e & $\bar{\nu}_e$ (K_L^o)
$\nu_\mu(\pi^+)$
$\bar{\nu}_\mu(\pi^-)$
$\nu_\mu(K^+)$
$\nu_e(K^+)$
$\bar{\nu}_e(K^-)$
$\bar{\nu}_\mu(K^-)$
ν_e & $\bar{\nu}_e(K_L^o)$
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0
100
200
NEUTRINO OR ANTINEUTRINO FLUX / GEV / SQUARE METER / 10^{13} PROTONS
E_ν (GEV)

Figure 1.

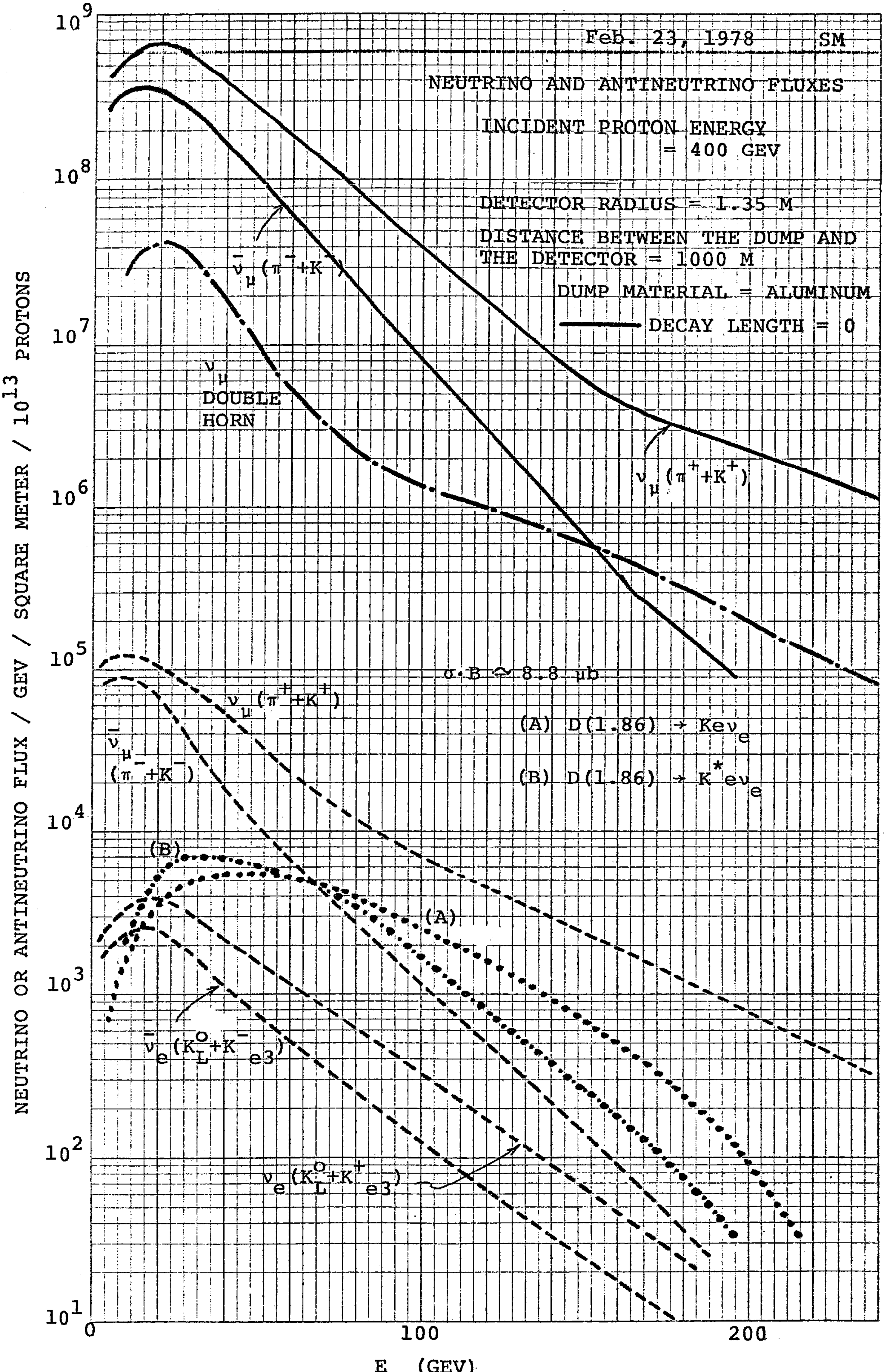
Feb. 23, 1978 SM
NEUTRINO AND ANTINEUTRINO FLUXES
INCIDENT PROTON ENERGY = 400 GEV
DETECTOR RADIUS = 1.35 M
DISTANCE BETWEEN THE DUMP AND THE DETECTOR = 1000 M
DUMP MATERIAL = ALUMINUM
DECAY LENGTH = 0
$\bar{\nu}_\mu(\pi^- + K^-)$
ν_μ DOUBLE HORN
$\nu_\mu(\pi^+ + K^+)$
$\sigma \cdot B \simeq 8.8\ \mu b$
$\nu_\mu(\pi^+ + K^+)$
(A) $D(1.86) \to K e \nu_e$
(B) $D(1.86) \to K^* e \nu_e$
$\bar{\nu}_\mu$
$(\pi^- + K^-)$
(B)
(A)
$\bar{\nu}_e(K_L^0 + K^-{}_{e3})$
$\nu_e(K_L^0 + K^+{}_{e3})$
NEUTRINO OR ANTINEUTRINO FLUX / GEV / SQUARE METER / 10^{13} PROTONS
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0
100
200
E_ν (GEV)

Figure 2.

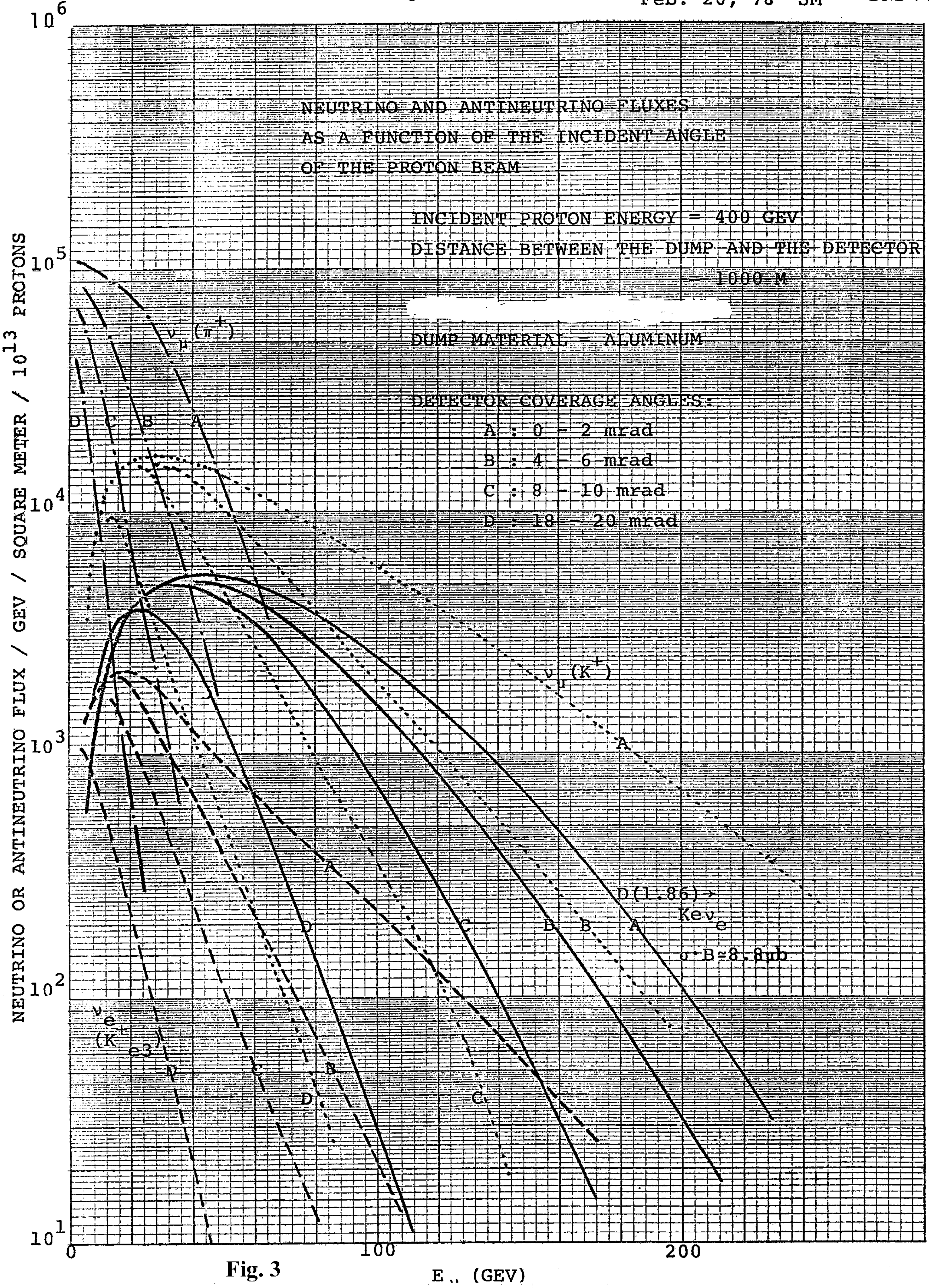
NEUTRINO AND ANTINEUTRINO FLUXES
AS A FUNCTION OF THE INCIDENT ANGLE
OF THE PROTON BEAM
INCIDENT PROTON ENERGY = 400 GEV
DISTANCE BETWEEN THE DUMP AND THE DETECTOR
= 1000 M
DUMP MATERIAL = ALUMINUM
DETECTOR COVERAGE ANGLES:
A : 0 - 2 mrad
B : 4 - 6 mrad
C : 8 - 10 mrad
D : 18 - 20 mrad
$\nu_\mu(\pi^+)$
$\nu_\mu(K^+)$
D(1.86) → $K e \nu_e$
$\sigma \cdot B \cong 8.8 \mu b$
ν_e
(K^+_{e3})
D
C
B
A
10^1
10^2
10^3
10^4
10^5
10^6
0
100
200
NEUTRINO OR ANTINEUTRINO FLUX / GEV / SQUARE METER / 10^{13} PROTONS
E_ν (GEV)

Fig. 3

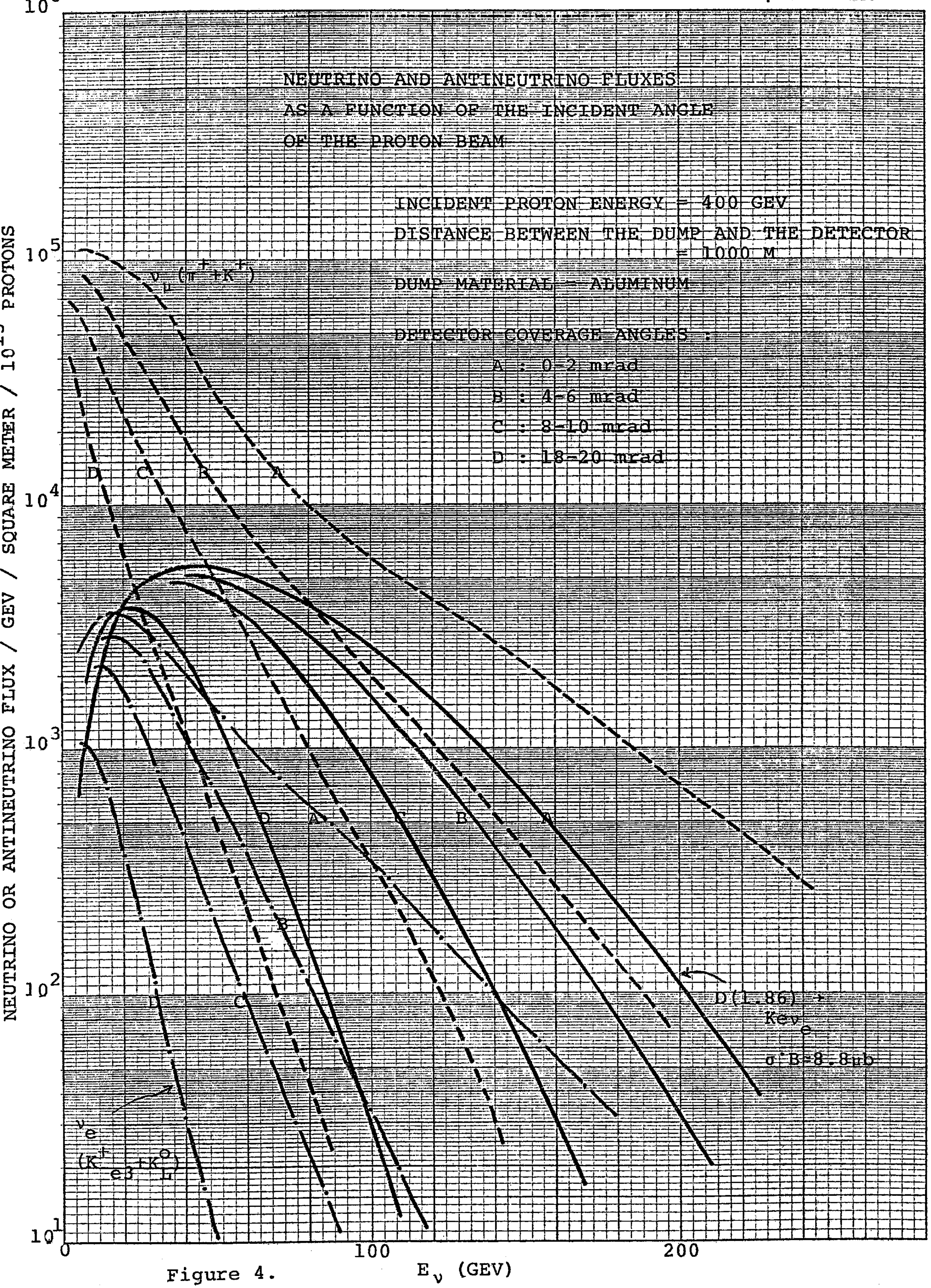
NEUTRINO AND ANTINEUTRINO FLUXES
AS A FUNCTION OF THE INCIDENT ANGLE
OF THE PROTON BEAM
INCIDENT PROTON ENERGY = 400 GEV
DISTANCE BETWEEN THE DUMP AND THE DETECTOR
= 1000 M
DUMP MATERIAL = ALUMINUM
DETECTOR COVERAGE ANGLES :
A : 0-2 mrad
B : 4-6 mrad
C : 8-10 mrad
D : 18-20 mrad
$\nu_\mu(\pi^+ + K^+)$
D C B A
D A C B A
B
D C
D(1.86) → $K e \nu_e$
$\sigma \cdot B = 8.8 \mu b$
ν_e
$(K^+_{e3} + K^0_L)$
NEUTRINO OR ANTINEUTRINO FLUX / GEV / SQUARE METER / 10^{13} PROTONS
10^6
10^5
10^4
10^3
10^2
10^1
0
100
200
E_ν (GEV)

Figure 4.

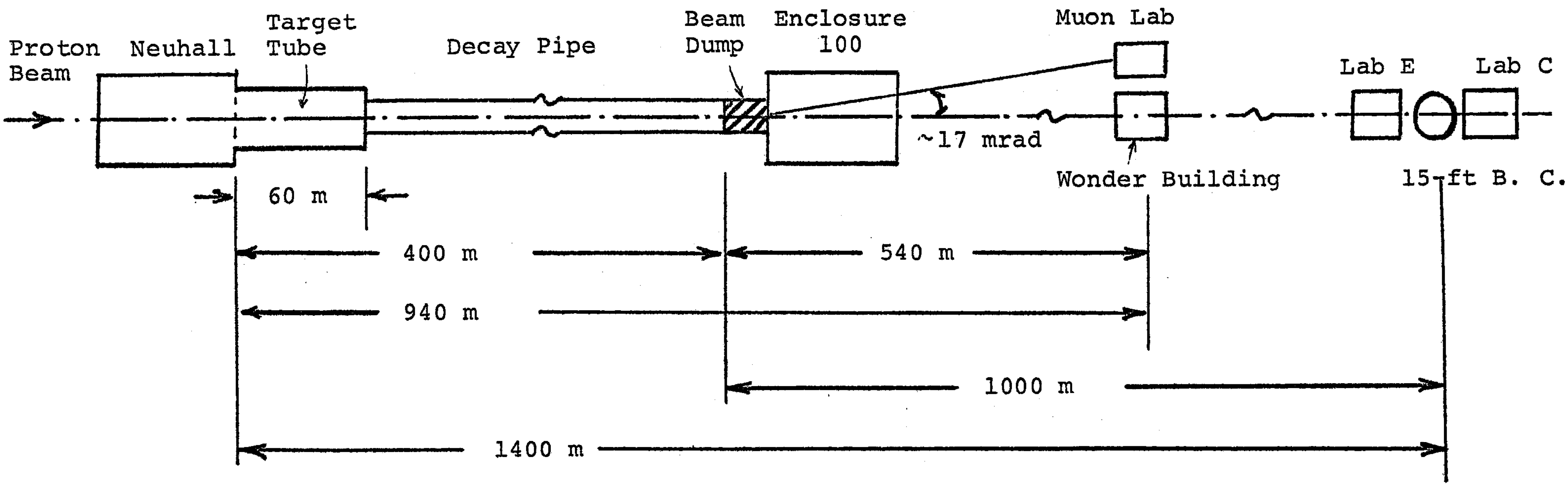

Figure 5. Schematic drawing of the physical layout of the Neuhall, Target Tube, Decay Pipe, Beam Dump, Enclosure 100, and the neutrino detectors.

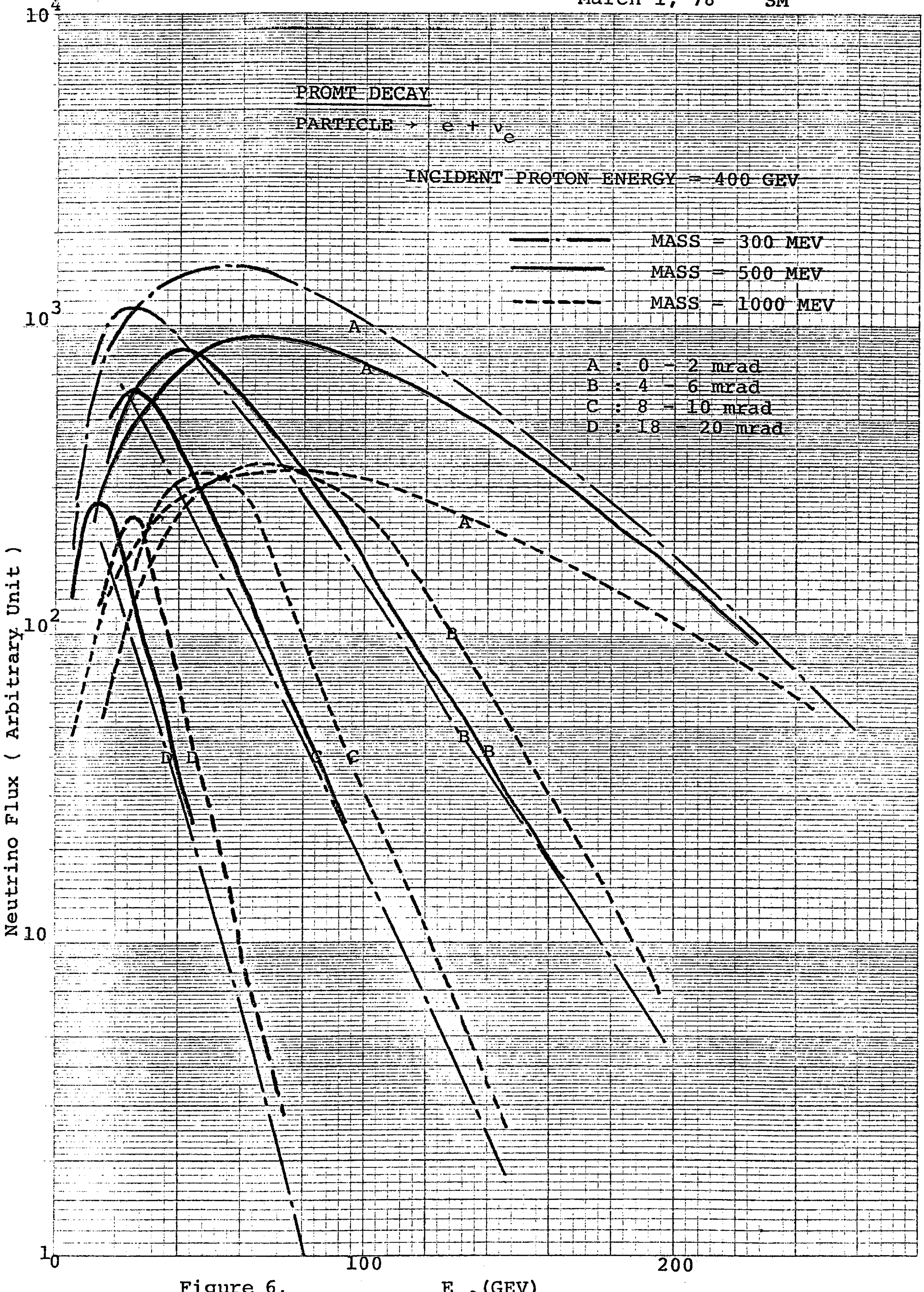
PROMT DECAY
PARTICLE → e + ν_e
INCIDENT PROTON ENERGY = 400 GEV
MASS = 300 MEV
MASS = 500 MEV
MASS = 1000 MEV
A : 0 - 2 mrad
B : 4 - 6 mrad
C : 8 - 10 mrad
D : 18 - 20 mrad
A
A
A
B
B
B
C
C
D
D
10^4
10^3
10^2
10
1
0
100
200
Neutrino Flux (Arbitrary Unit)
E_ν (GEV)

Figure 6.